INSPIRE Final Presentation

August 5th 2010

All photos provided by: NASA photographer, Thomas P. Tschida and INSPIRE Team

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Agenda

- Introduction of Program and Project
- Analysis of Performance and Aerodynamics
  - Lift and Drag
  - Static Thrust
  - Thrust Required
  - Rate of Climb
  - Take-off Distance
  - Flight Endurance
  - Level Turn Performance
  - Airspeed Calibration
- Moments of Inertia

What is INSPIRE

- Interdisciplinary National Science Project Incorporating Research and Education Experience
  - Provide practical research experience
  - Provide professional career development information
  - Allow students to discover and utilize a network of resources
  - Established to motivate students to pursue STEM careers

The Project

- To Analyze the Aerodynamic and Performance Characteristics of the DROID 3
- Flight testing helped to validate our predictions and determine the capabilities of the DROID 3

The Steps

- Learning about Aerodynamics
- Measuring the Plane
- Calculating Aerodynamic and Performance Characteristics
- CDR (Critical Design Review)
- Creation of Flight Procedures
- Tech Brief
- Flight Testing
- Analysis of Data
- Final Presentation

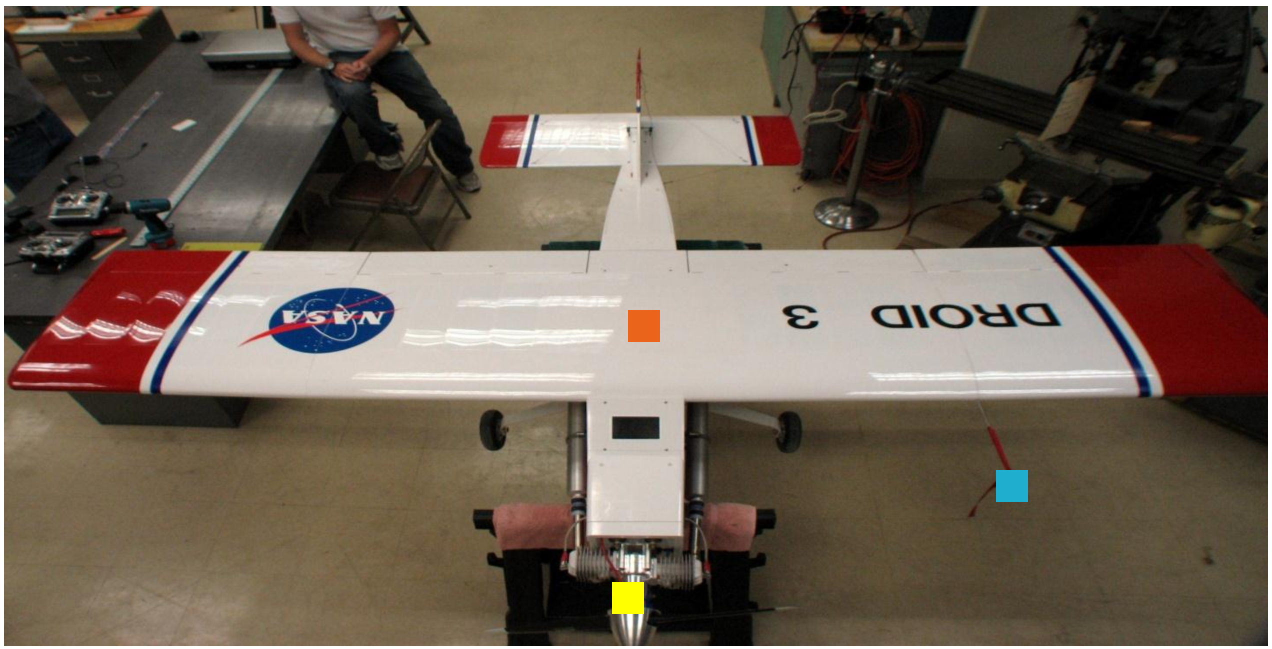
The DROID 3

- Wingspan: 9 feet 8.5 inches
- Total Length: 8 feet
- Chord: 2 feet 1.5 inches

Vehicle Configuration

Full weight: 44.96 lbs

CG: 7” from leading edge of wing



■ – On-board Piccolo ■ –Pitot tube/ Static port ■ – Tachometer

Lift and Drag

Lift and Drag

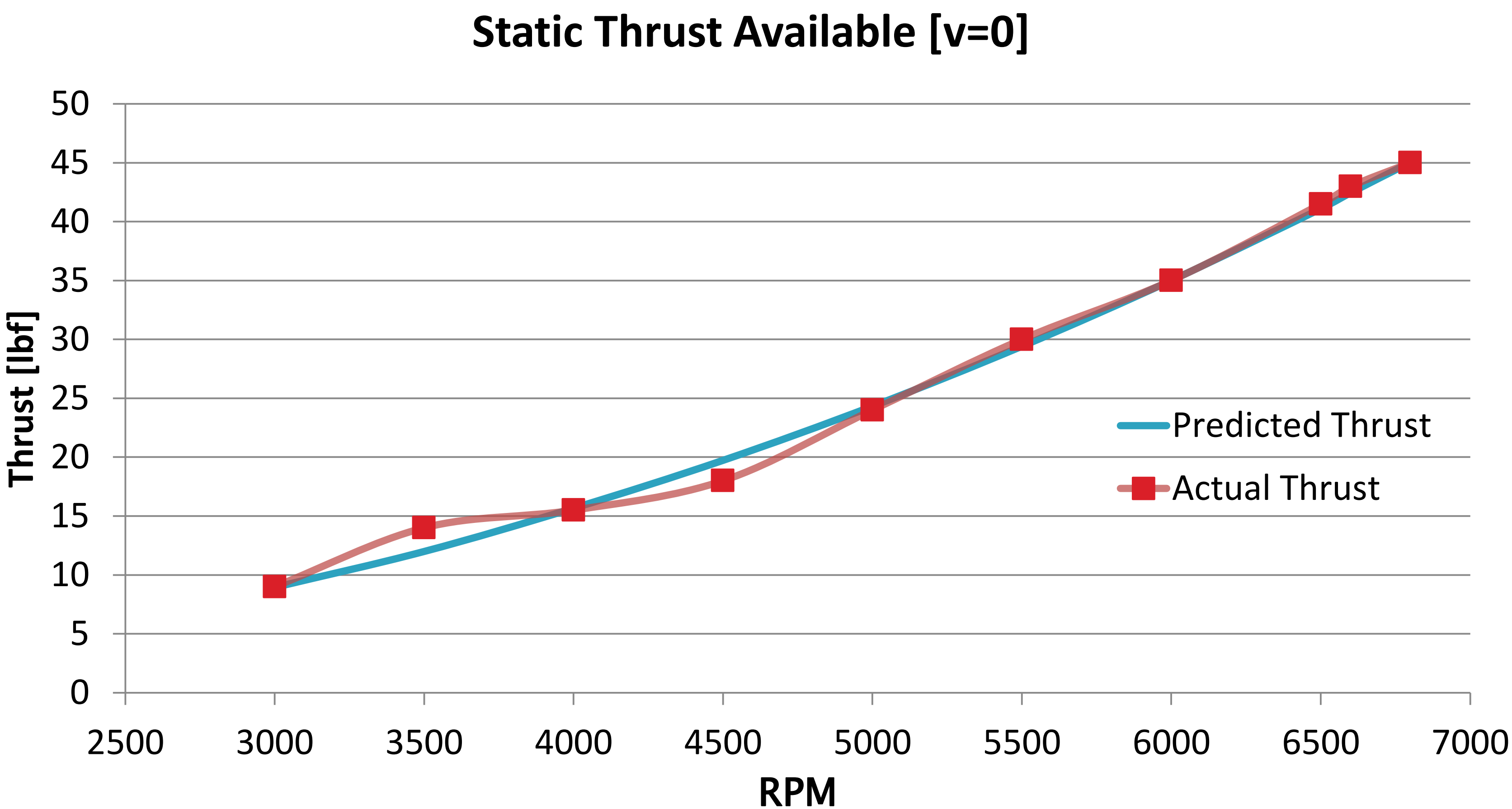
- Lift and Drag were found by considering the glide ratio, forward motion over downward motion, considered equal to L/D when thrust is absent.
- At 0 degree flaps L/D= 7.78
- At 15 degree flaps L/D= 6.35
- At 32 degree flaps L/D=5.34

Static Thrust

Static Thrust

- Prediction: PropCalc
  - Determined an approximate RPM
  - Dimensions of propeller: 26x10
- Testing: Force gauge connected to tail of DROID
  - Different throttle settings
  - Recorded the RPM

Static Thrust



Thrust Required for Level Flight

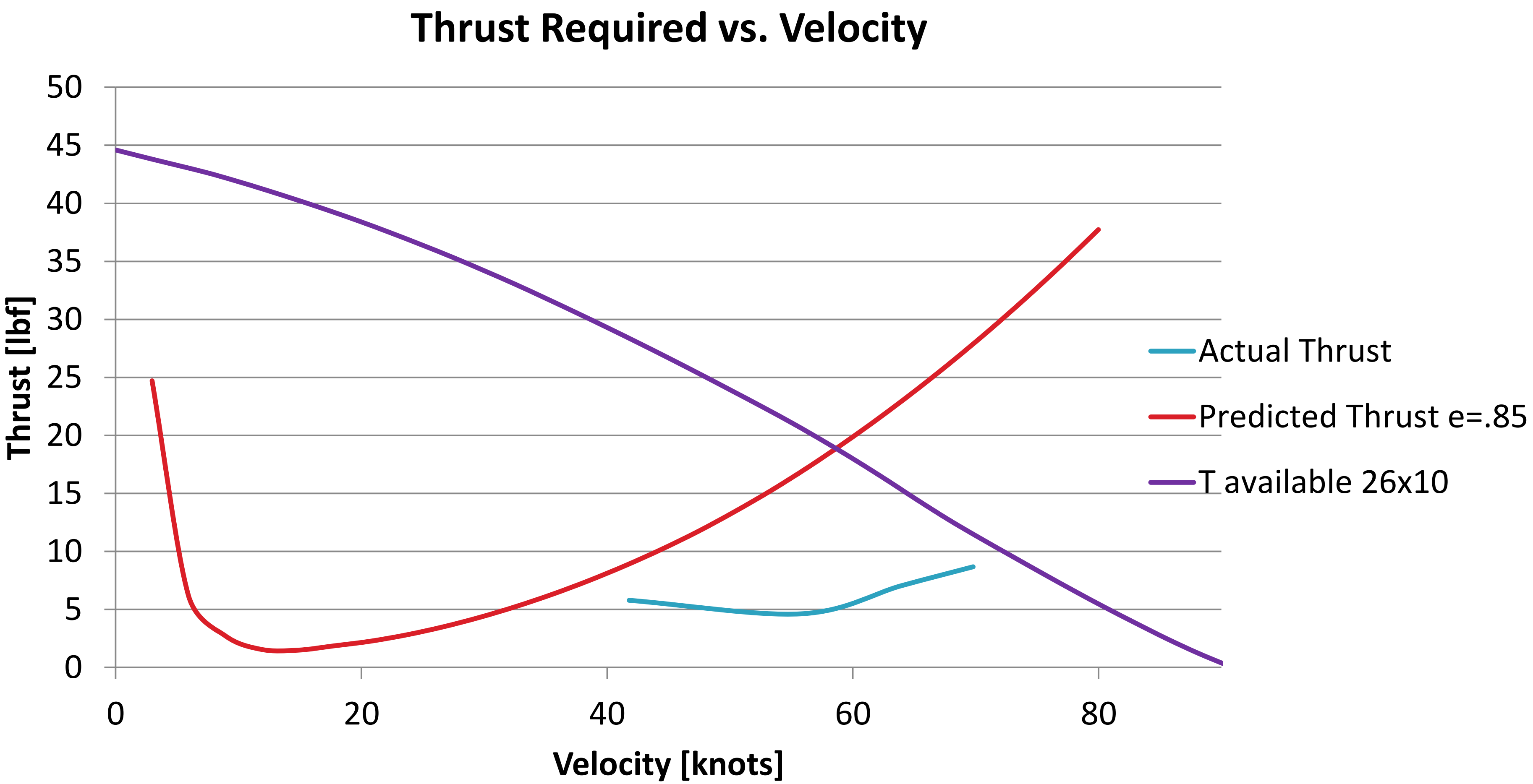
Thrust Required

- Initial Equation:

$$T_{required} = \frac{W}{C_L / C_D}$$

- Flight Testing:
  - Used the RPM, airspeed, and propeller dimensions
  - Inserted the propeller dimensions and RPM into PropCalc
  - Several graphs with one point from each graph
  - Final graph of thrust required

Thrust Required

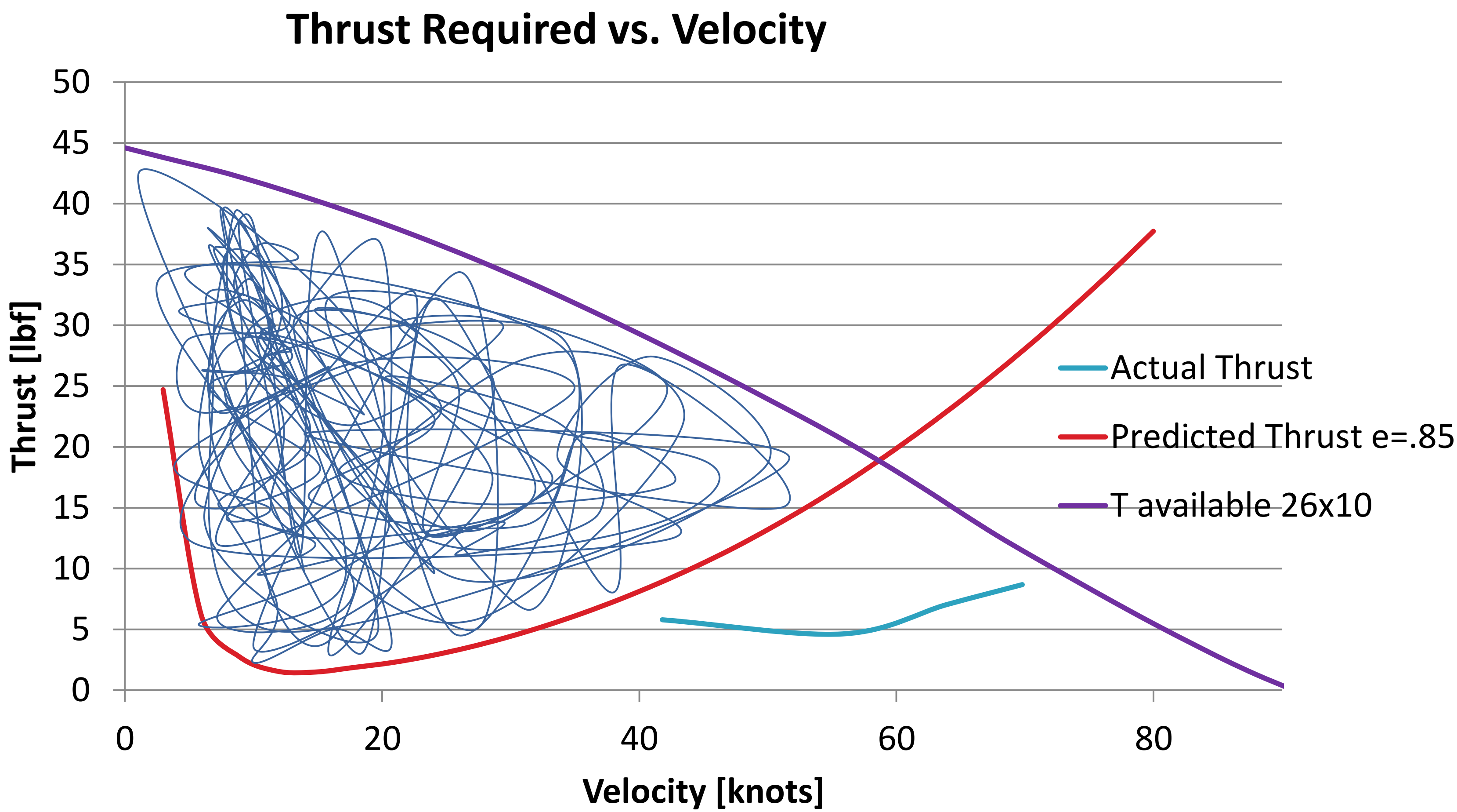


Thrust Required

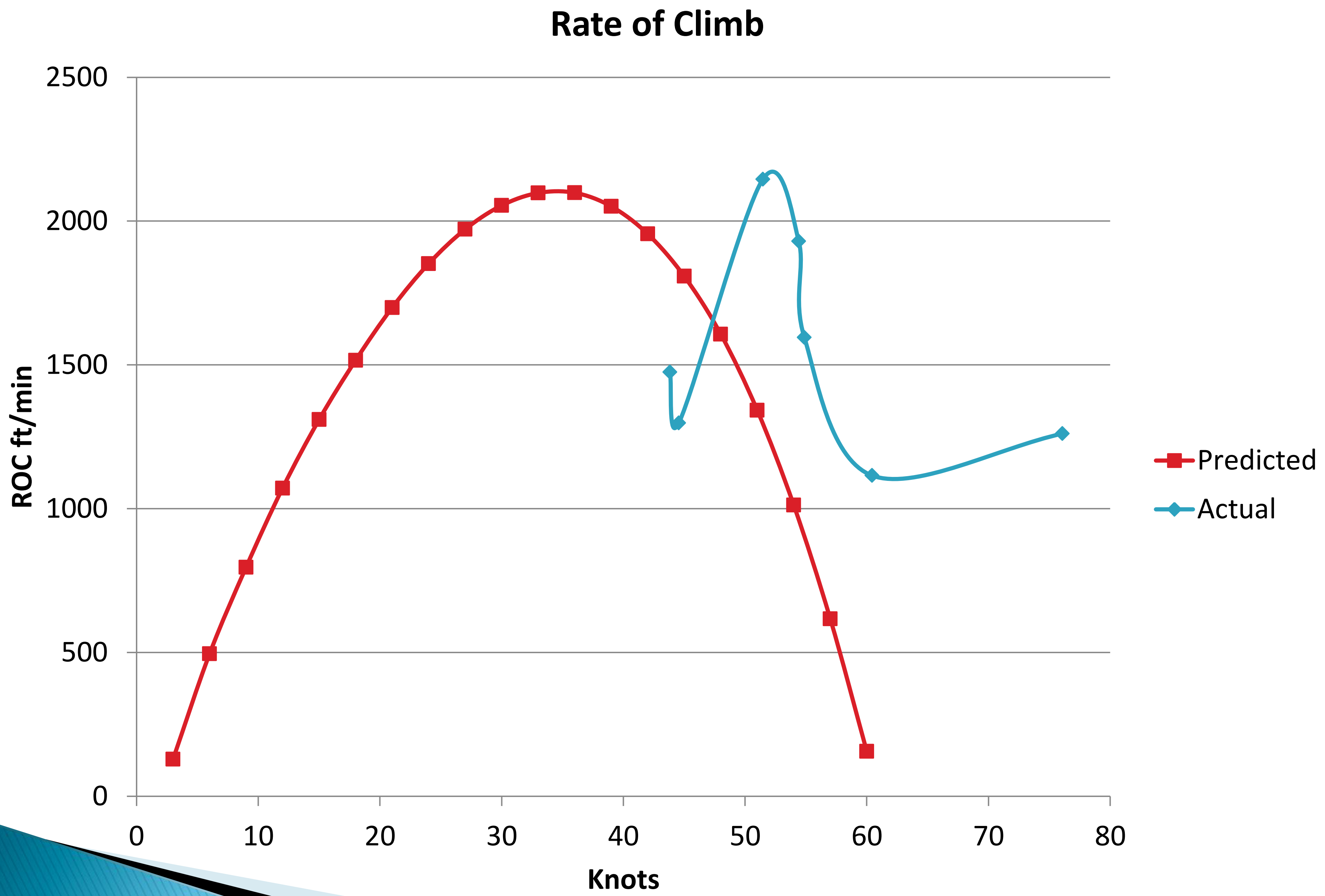
- Challenges:
  - Finding areas where the velocity and altitude were consistent
  - Roll angle was close to zero
  - Finding level flight for a good amount of time
  - Amount of data per second

Rate of Climb

Rate of Climb

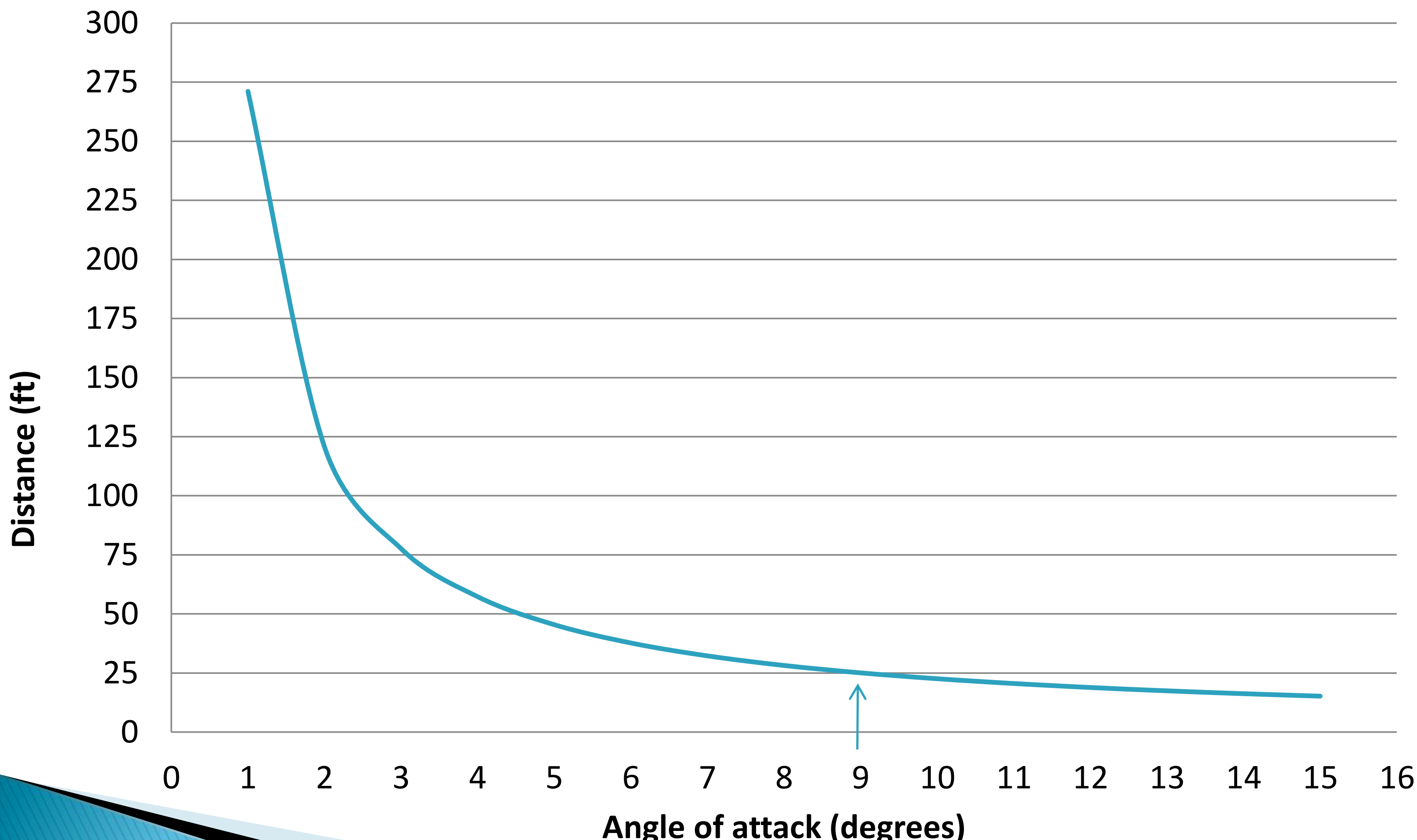


$$ROC = \frac{VT_{\text{ex}}}{W}$$

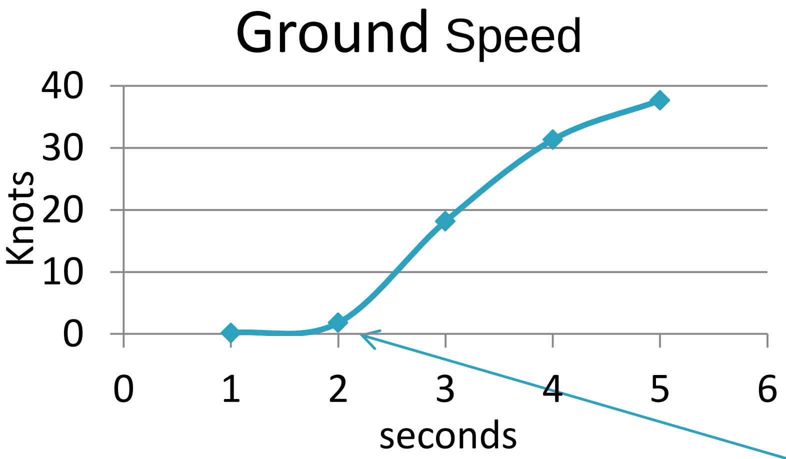

Rate of Climb
2500
2000
1500
1000
500
0
ROC ft/min
0
10
20
30
40
50
60
70
80
Knots
Predicted
Actual

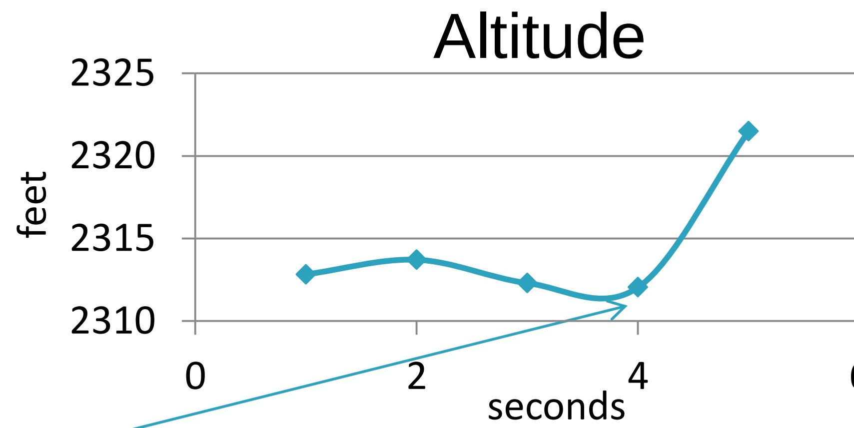
Take-off Distance

Prediction


Distance (ft)
300
275
250
225
200
175
150
125
100
75
50
25
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Angle of attack (degrees)

Test Data (Distance)



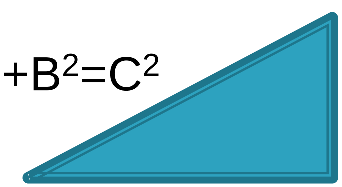


Take-off

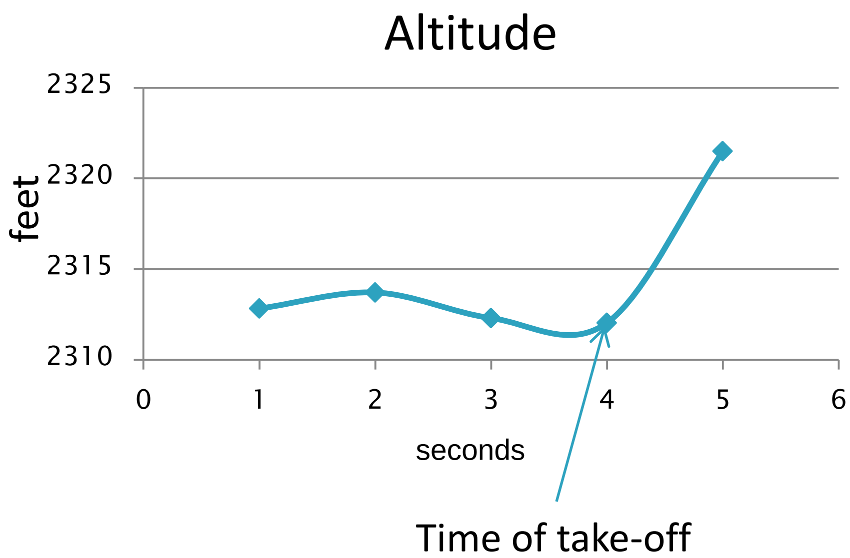
Latitude 0.00000389038 x 365228 = 0.3000886159 ft

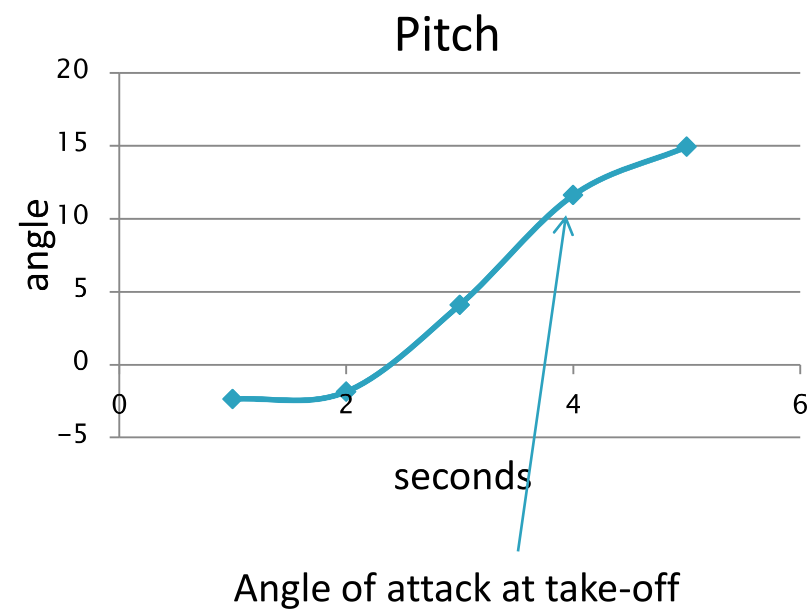
Longitude 0.00019722353 x 299656 = 25.365406128 ft

$A^2+B^2=C^2$



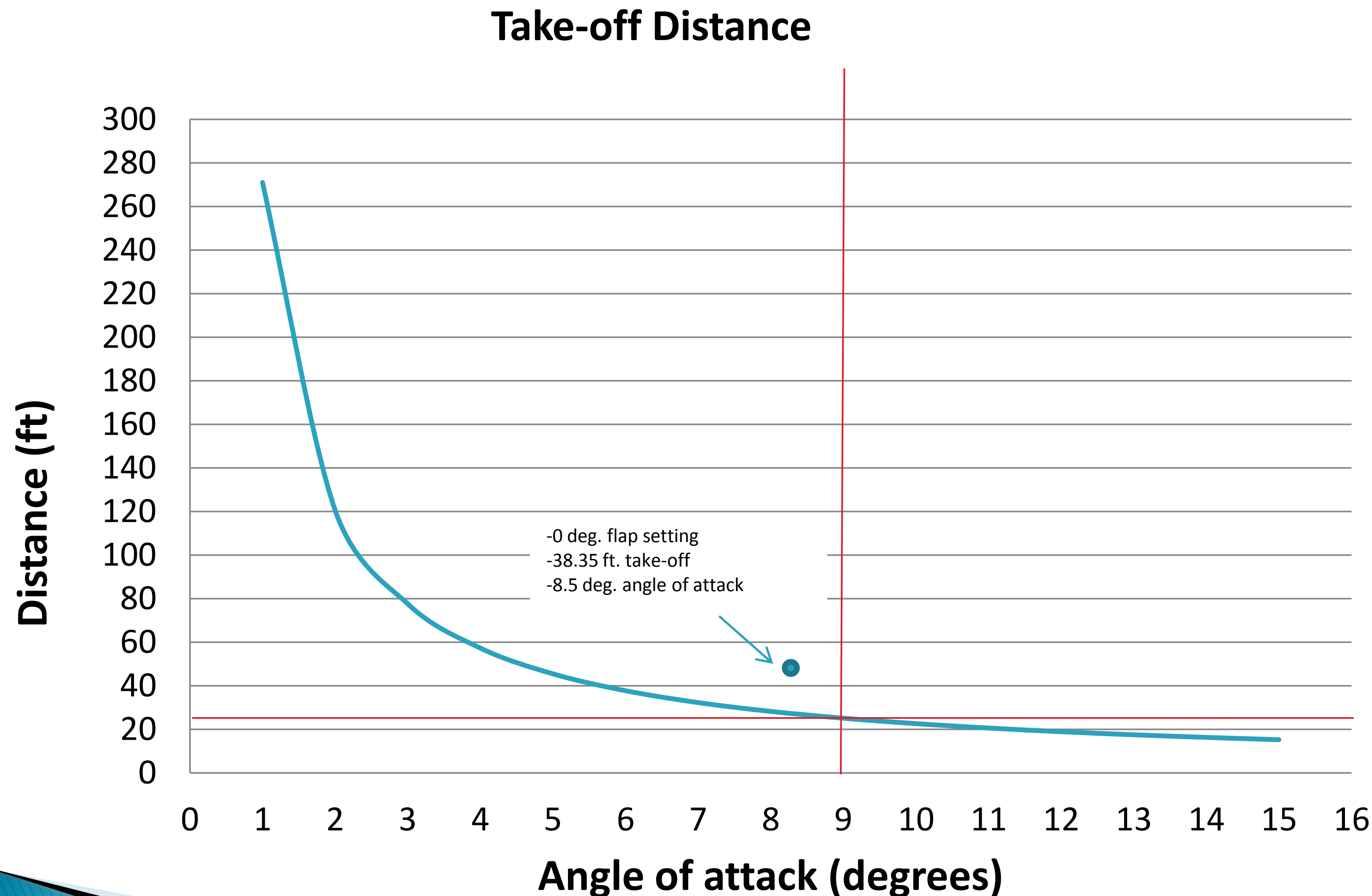
Test Data (Angle)



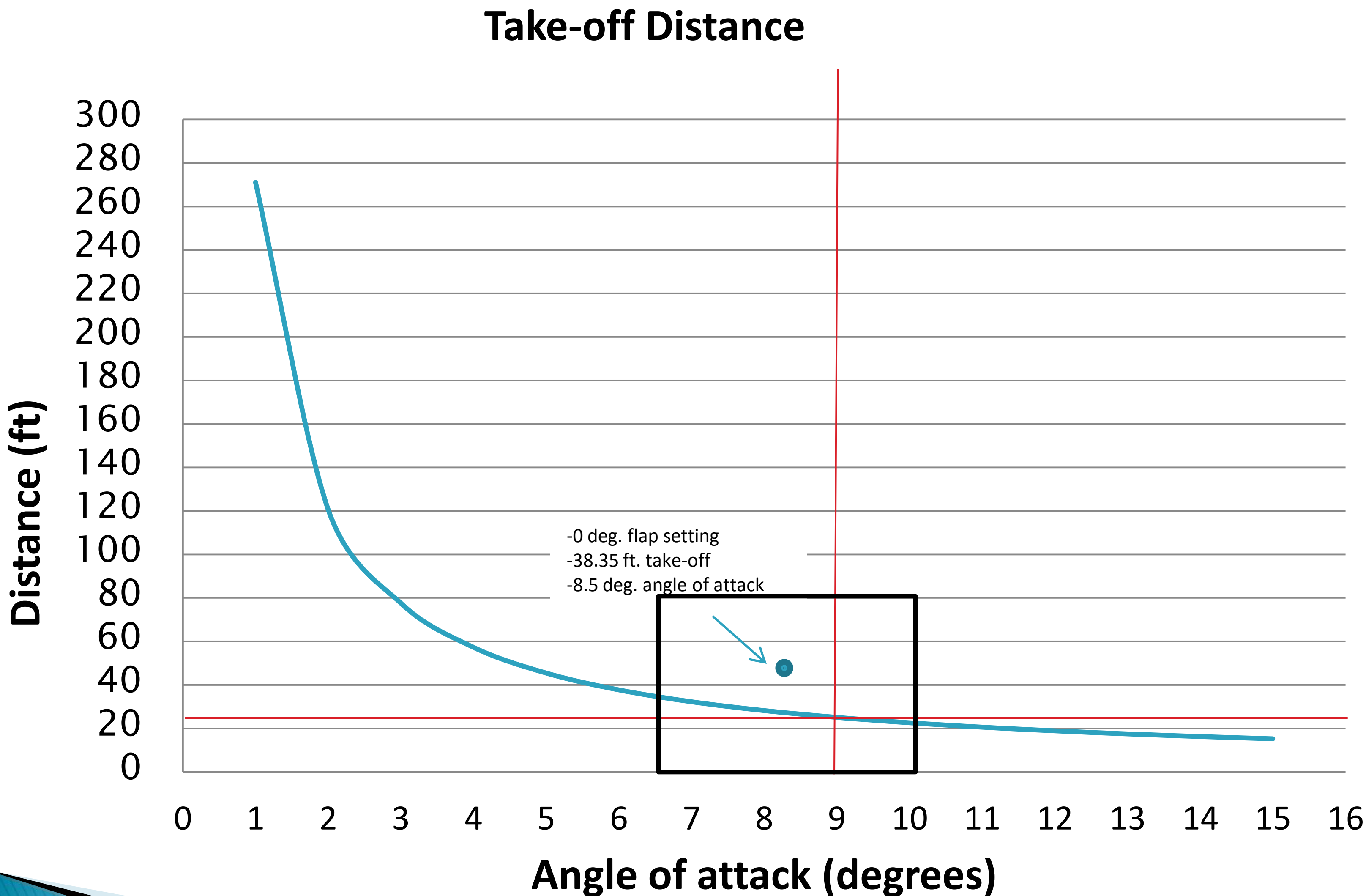


- Due to calibration of gyroscopic pitch sensor, ¾ of a degree must be added to given pitch to receive actual pitch

Data

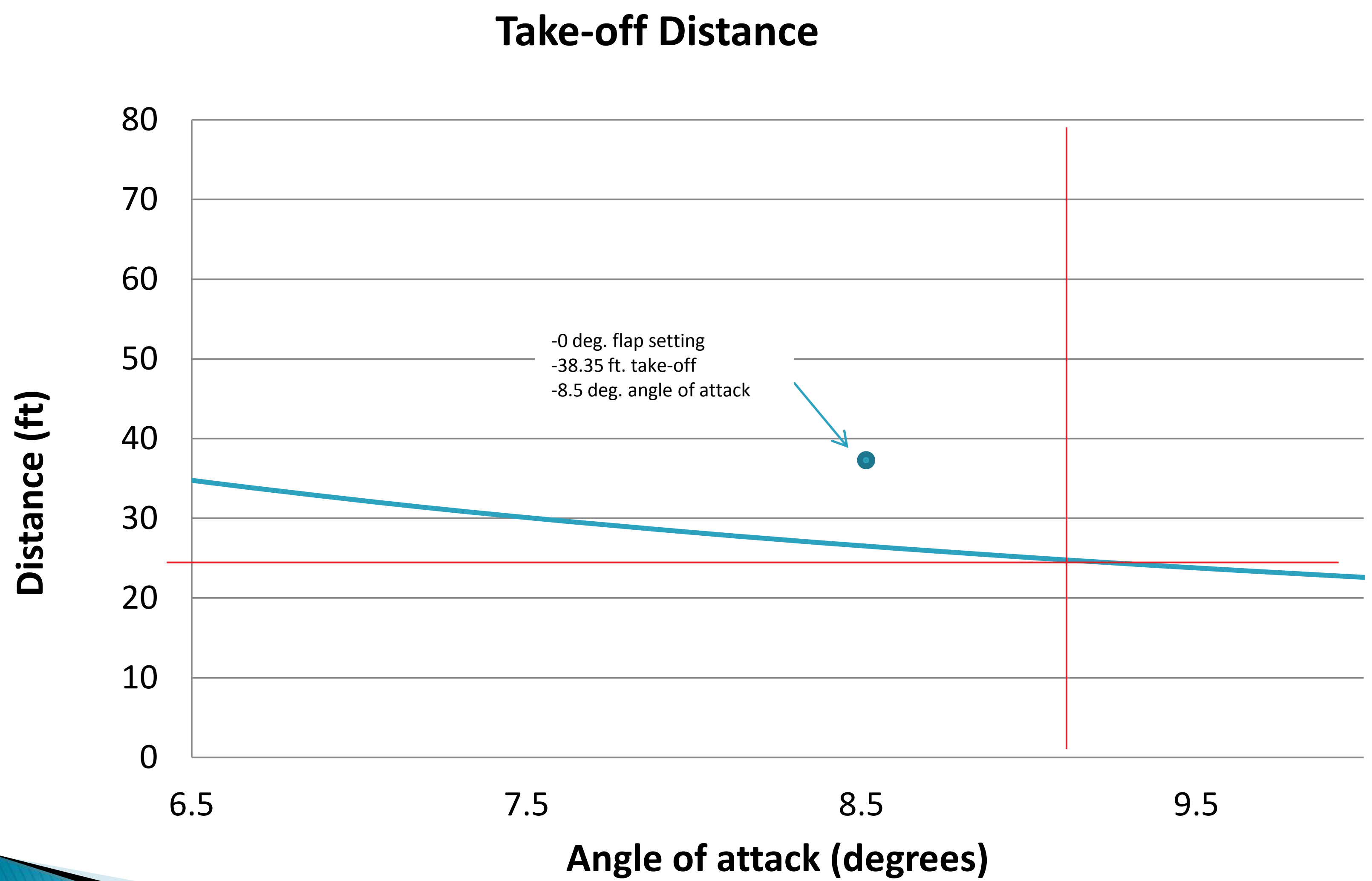

Take-off Distance
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Distance (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Angle of attack (degrees)
-0 deg. flap setting
-38.35 ft. take-off
-8.5 deg. angle of attack

Data



Take-off Distance
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Distance (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Angle of attack (degrees)
-0 deg. flap setting
-38.35 ft. take-off
-8.5 deg. angle of attack

Data


Take-off Distance
80
70
60
50
40
30
20
10
0
6.5
7.5
8.5
9.5
Distance (ft)
Angle of attack (degrees)
-0 deg. flap setting
-38.35 ft. take-off
-8.5 deg. angle of attack

Error Analysis

- Flight testing data was recorded at 1 Hz. Take-off was an estimated 1.5 seconds.
- Due to change in constants, analytical data was not applicable to take-off testing of 15 degree and 32 degree flaps settings

Findings

- 15 degree flap setting had a take-off distance of 31.28 feet
- 32 degree flap setting had a take-off distance of 44.88946

- For DROID 3 aircraft:
  - Use 15 degree flap setting for optimized take-off
  - Use 32 degree flap setting for optimized landing

Flight Endurance

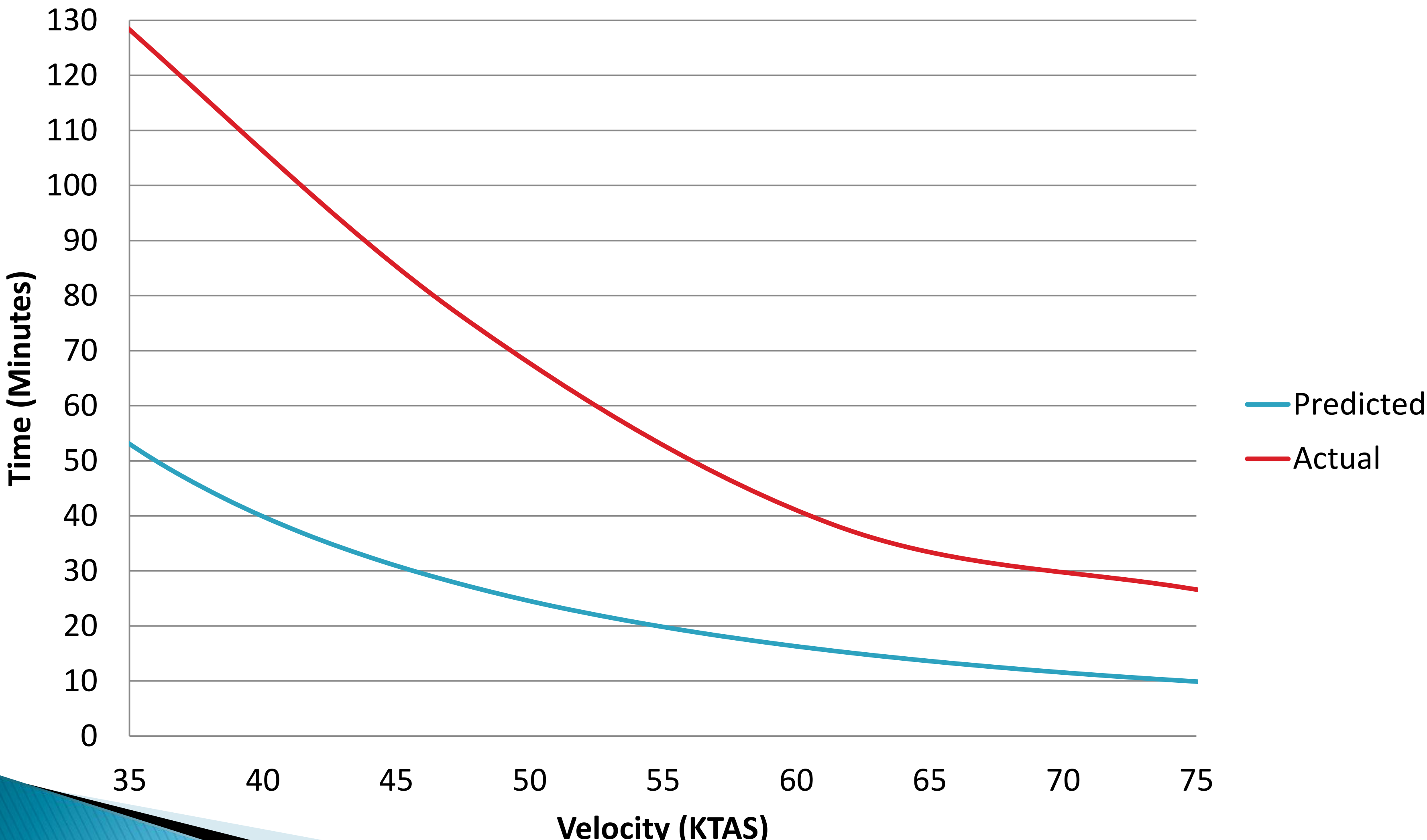
Flight Endurance

- Flight Testing
  - Ground Test
- Data

Initial Weight-19,033 grams		
RPM	Weight Diff.	Time
initial-3500	105g	10 min
3500-4500	130g	7 min
4500-5500	222g	6 min
5550-6500	270g	5 min

oz burned	oz per min	RPM	minutes on a full tank
3.70	0.37	3500	134.99
4.58	0.65	4500	76.32
7.83	1.30	5500	38.31
9.52	1.90	6500	26.24

Flight Endurance



Level Turn Performance

Level Turn Performance

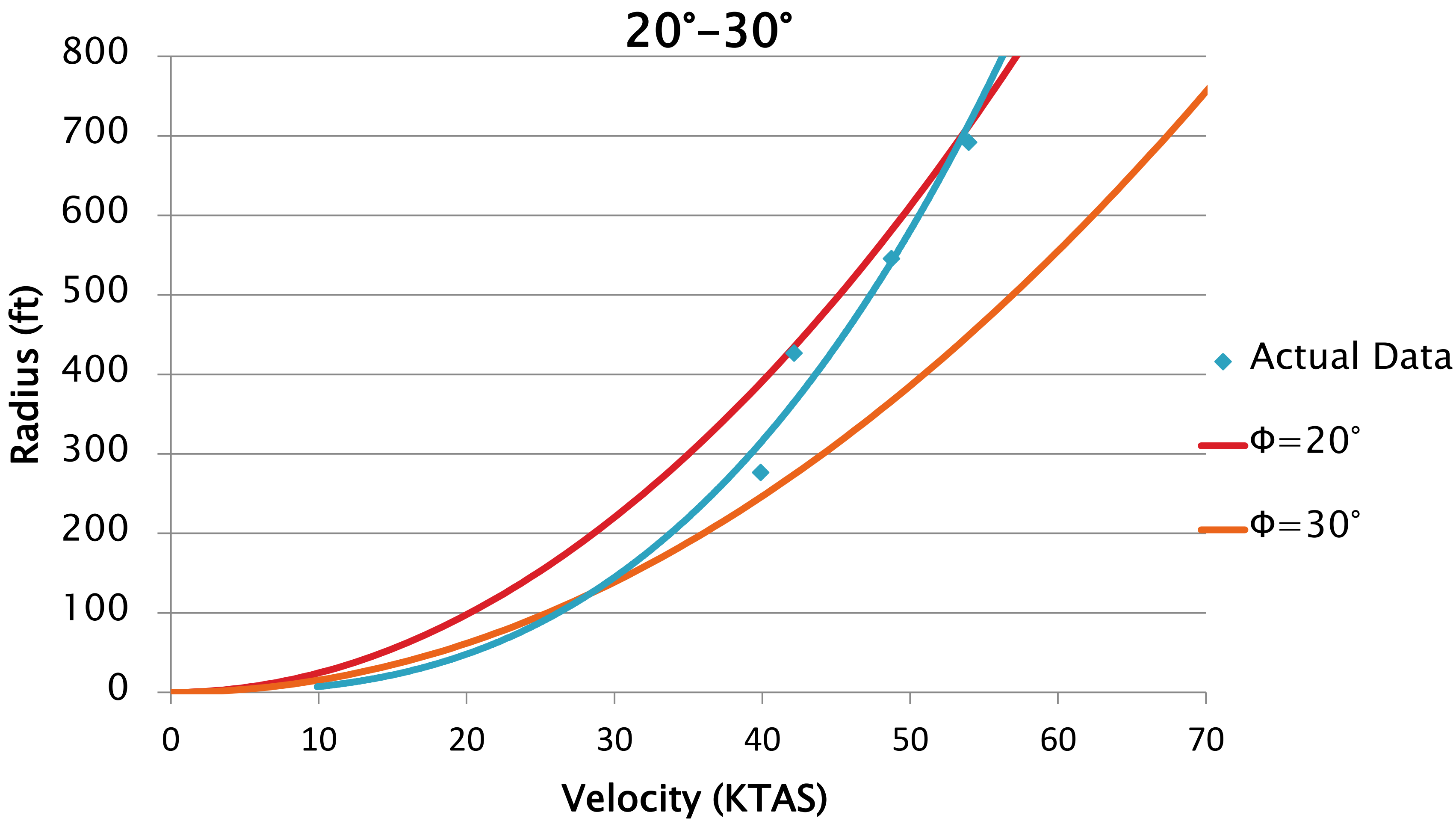
- Initial Equation:

$$R = \frac{V^2}{g \tan \phi}$$

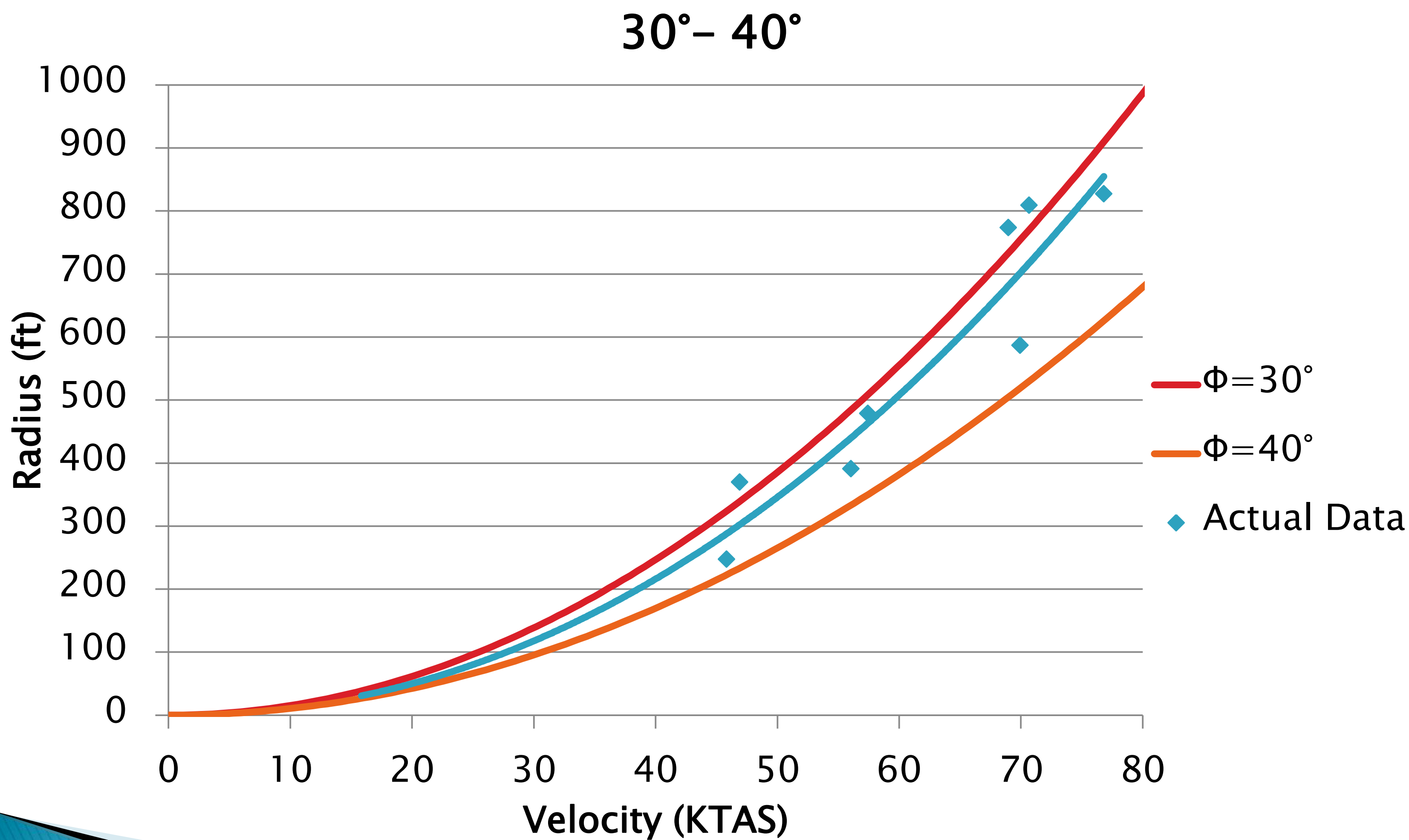
R= turn radius
V = velocity
g = acceleration due to gravity
Φ= bank angle

- Testing:
  - Fly multiple level turns at constant bank and velocity

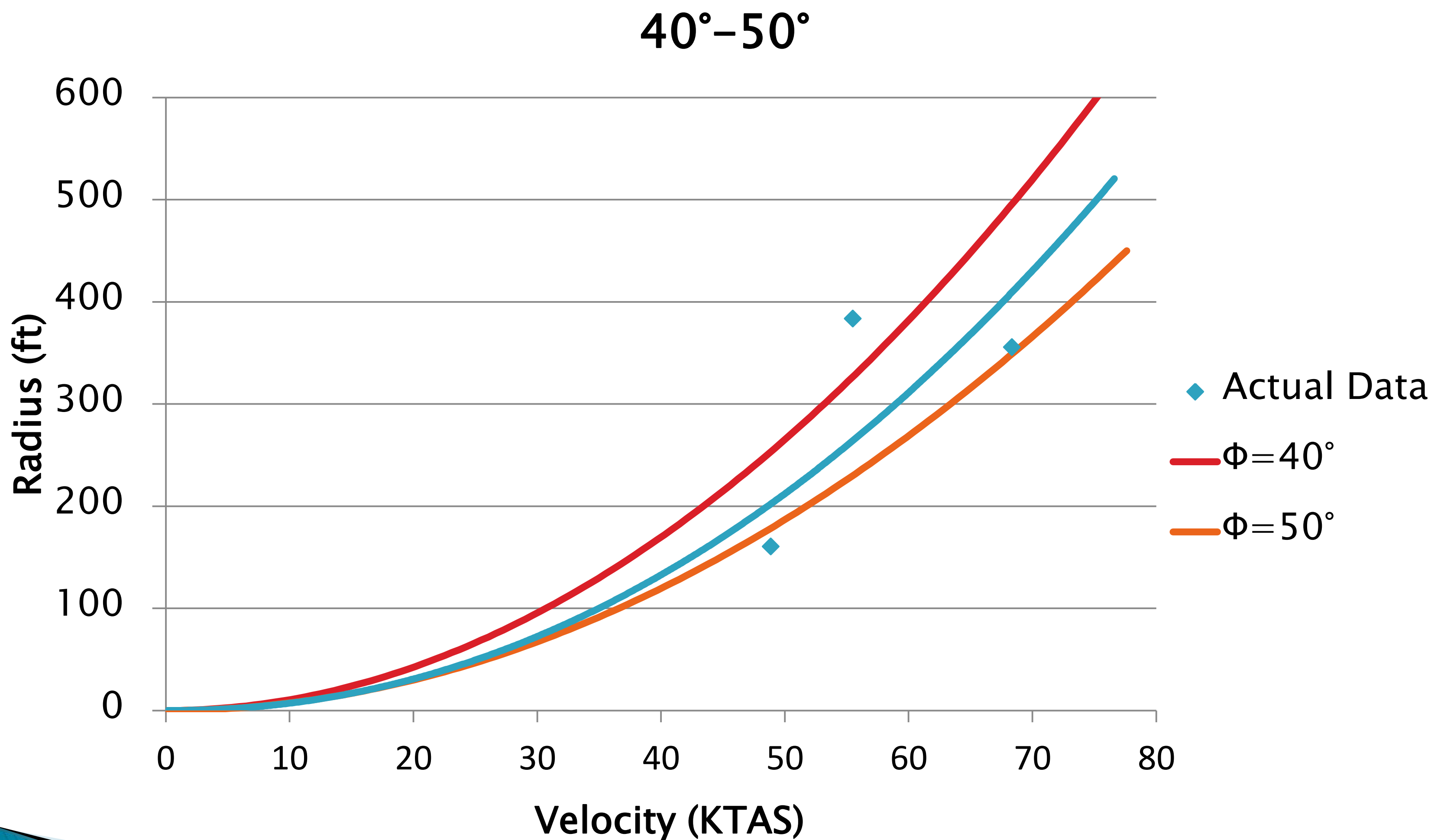
Level Turn Performance



Level Turn Performance



Level Turn Performance



Airspeed Calibration

Airspeed Calibration

			Results			
Trial	KTAS	Ground		Difference (Pitot-Ground)		
1	47.30318	47.79142		-0.48824		
2	53.84654	54.51497		-0.66843		
3	68.93083	72.25318		-3.32235		
4	67.86904	68.37338		-0.50434		

- Airspeed calibration factor calculated to be minute
- Calibration of −3.32KTAS was omitted as outlier
- Average calibration factor = −.55KTAS

Moments of Inertia

Moments of Inertia

- Find moment of inertia for I_{xx}, I_{yy}, and I_{zz}

$$\begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

Inertia tensor

Stress Testing–Simple Pendulum

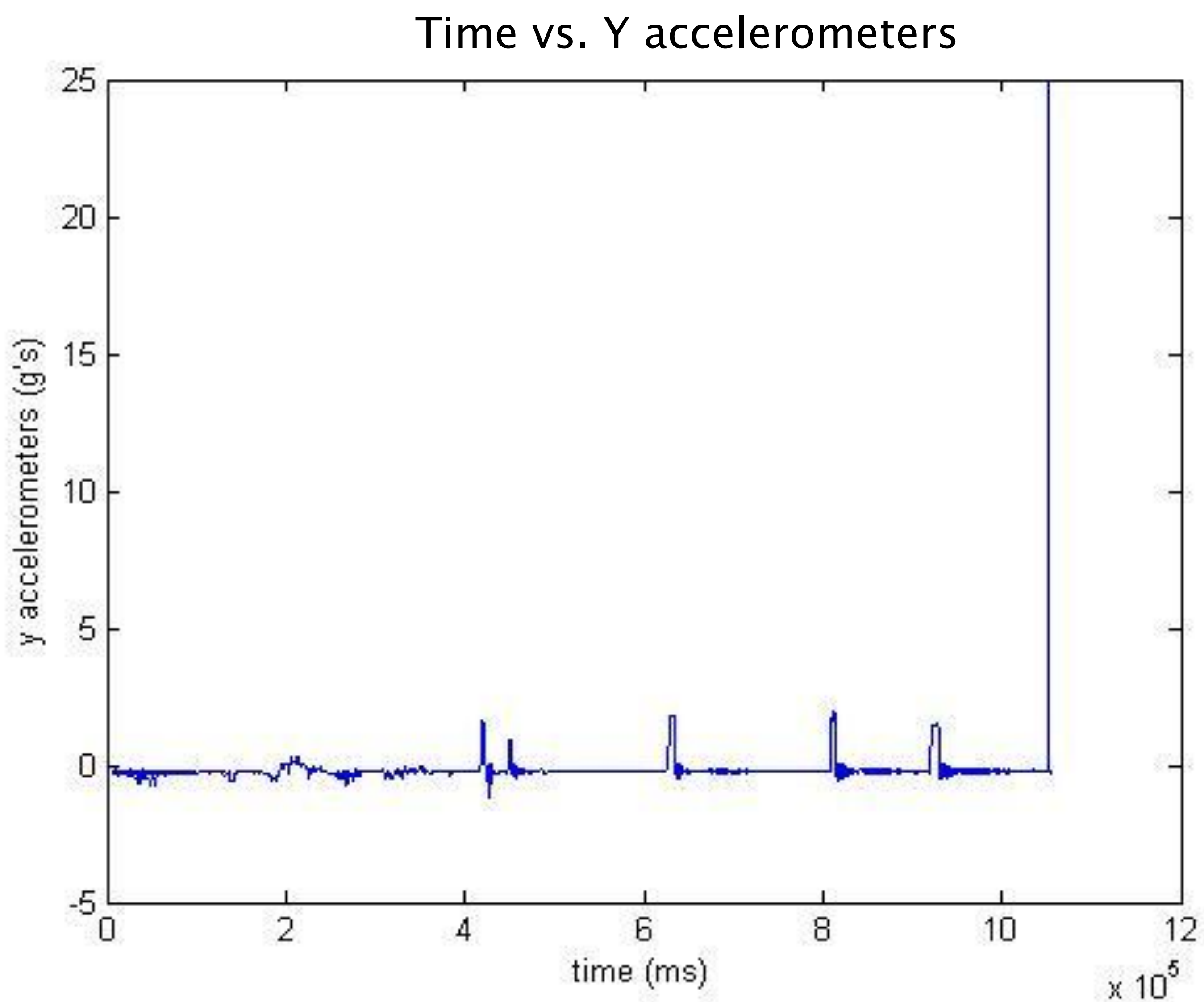
- Ensure that channel and metal bar can hold weight of aircraft
- Placed 100 lbs on channel
- Allowed to sit for 10 minutes
- Successful!

Stress Testing– Bifilar

- Followed same procedure as before, only now testing strength of cables
- At 90 lbs, the universal joints broke apart
- Failed stress test
- Retested with stronger universal joints, and was successful

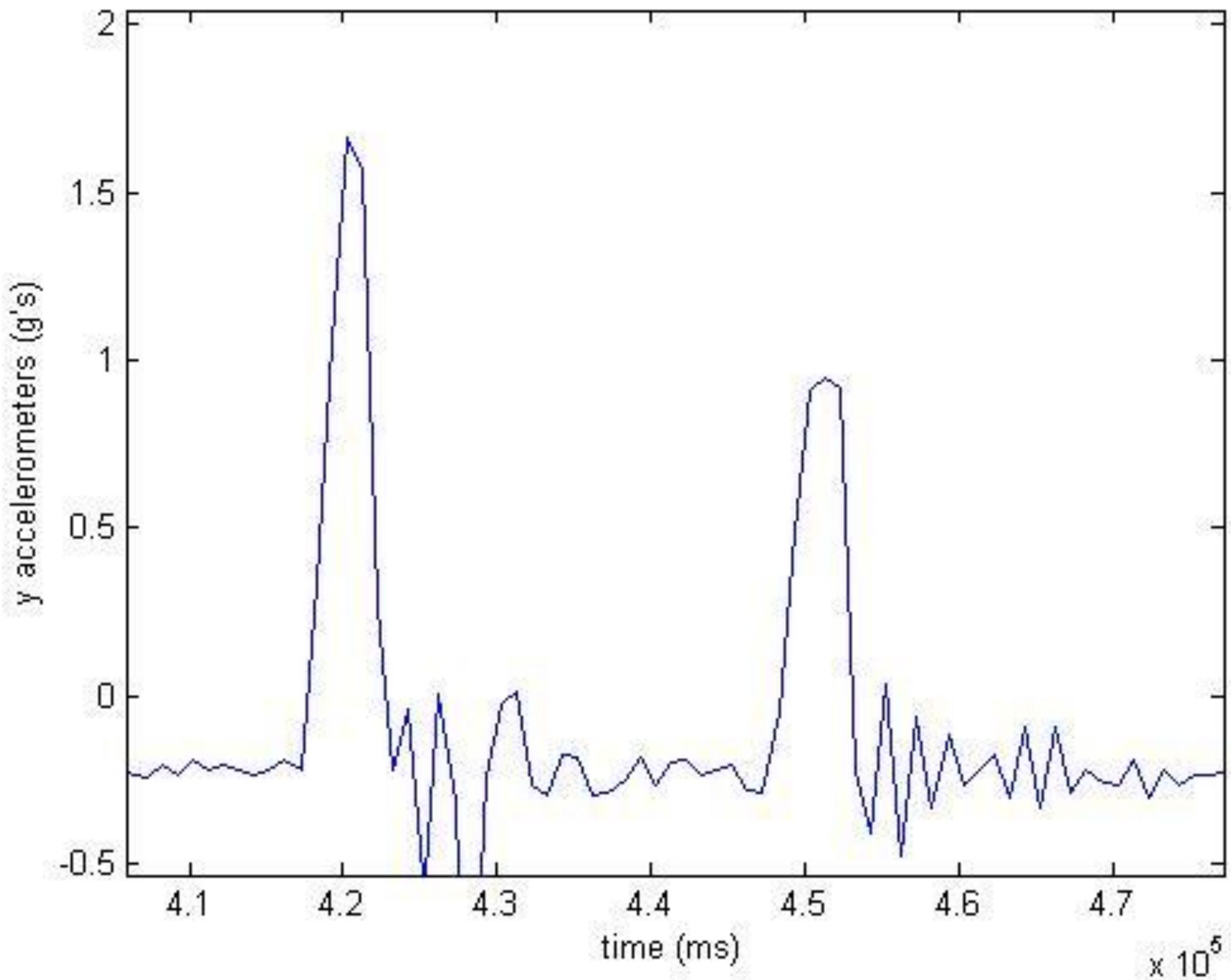

TEST

Roll Inertia Test



Roll Inertia Test

Time vs. Y accelerometers (zoom)



Roll Inertia Test

- Poor data due to uncontrollable secondary oscillations
- Will use stopwatch data instead
- T = 2.28 seconds

Simple Pendulum

Roll Inertia Results

Rotational inertia about pivot point

$$I'_{xx} = \frac{WT^2L}{4\pi^2}$$

W= weight of aircraft and rig (lbs)
T=period (sec)
L= length of pendulum (ft)

Using parallel axis theorem…

$$I_{xx} = I'_{xx} - \frac{WL^2}{g} - I_{rig}$$

Rotational inertia about aircraft's axis

Roll Inertia Results

$$I'_{xx} = \frac{(51.115lbs)(2.28sec)^2(3ft)}{16\pi^2} = \boxed{20.207\ slugs \cdot ft^2}$$

$$Translational\ MOI = \frac{(51.115lbs)(3ft)}{32.2ft/sec^2} = \boxed{14.298\ slugs \cdot ft^2}$$

$$I_{rig} = \boxed{0.0393slugs \cdot ft^2}$$

$$I_{xx} = 20.207slugs \cdot ft^2 - 14.298slugs \cdot ft^2 - 0.0393slugs \cdot ft^2$$

Roll Inertial Results

Measured

$$I_{xx} = 5.8697\ slugs \cdot ft^2$$

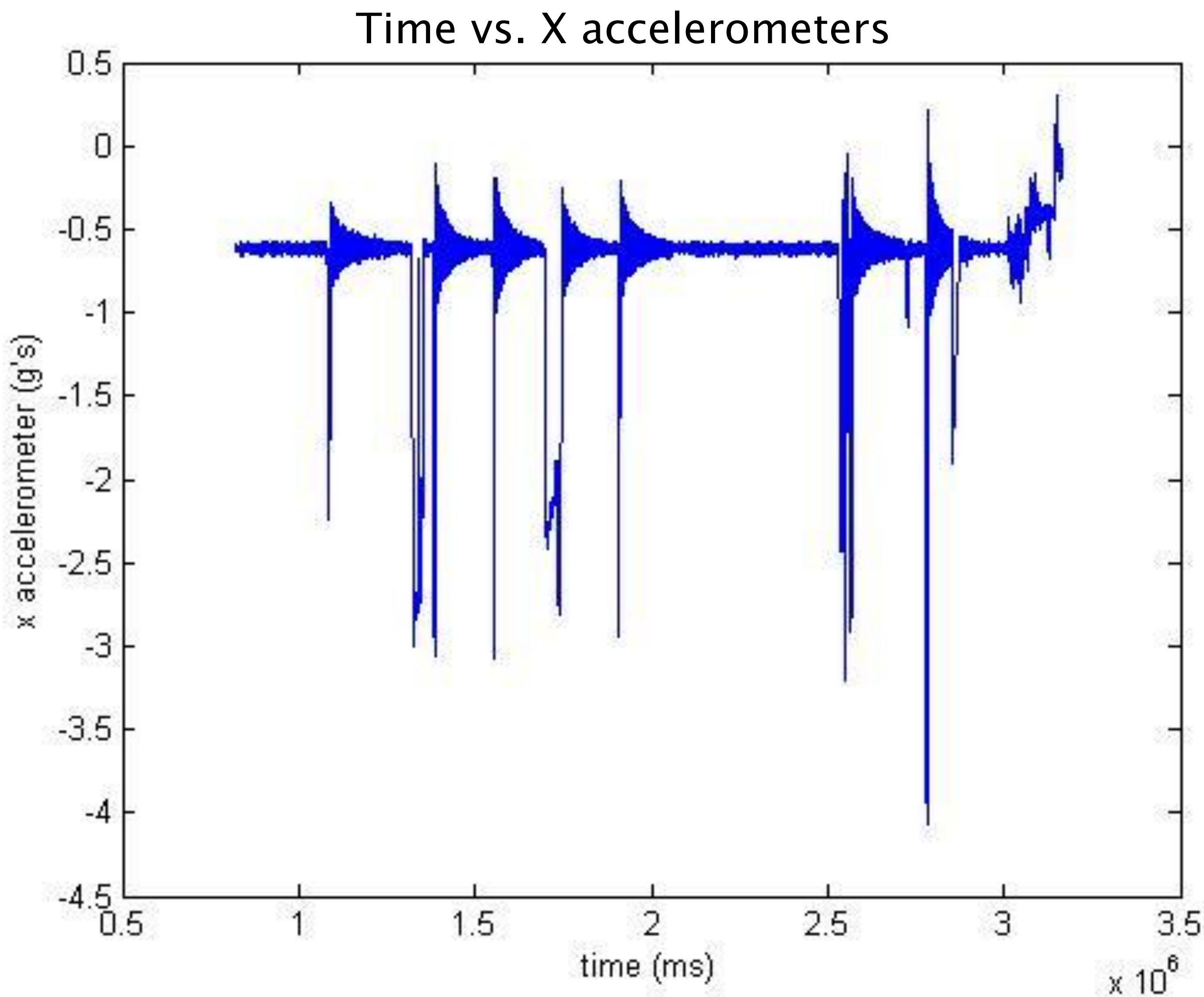
Estimated

$$I_{xx} = 4.254\ slugs \cdot ft^2$$

Percent Error

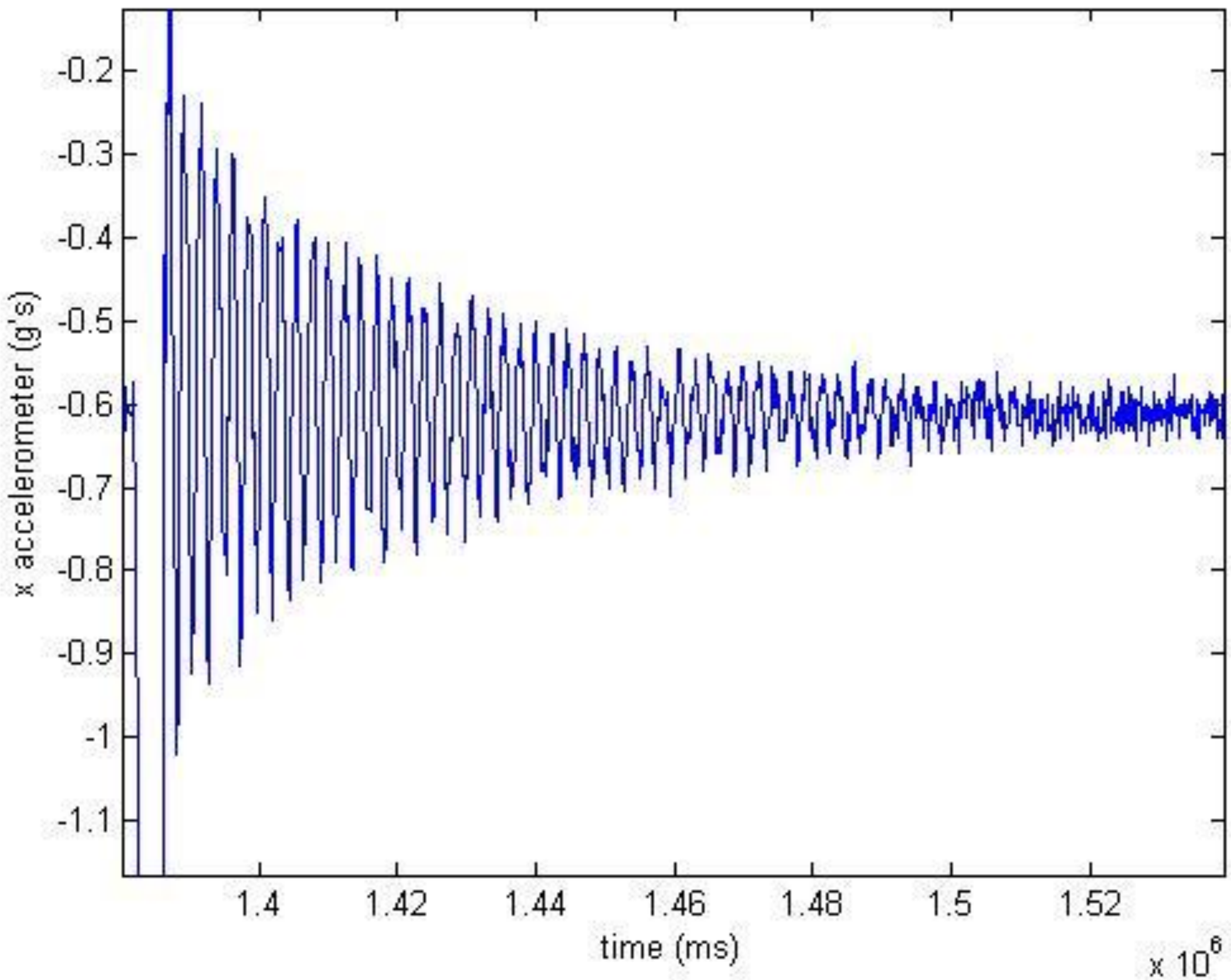
38%

Pitch Inertia Test



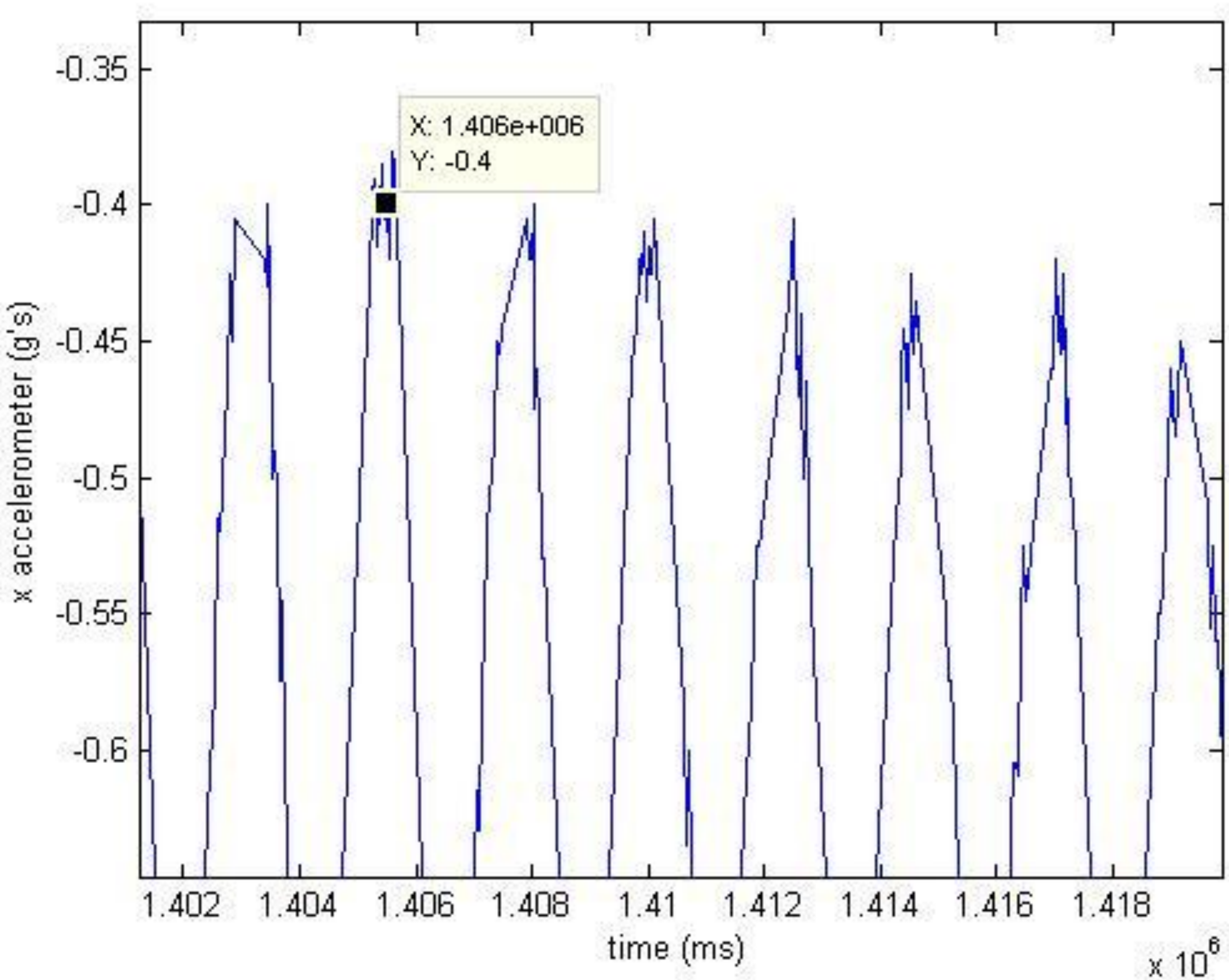
Pitch Inertia Test

Time vs. X accelerometers (1 oscillation)



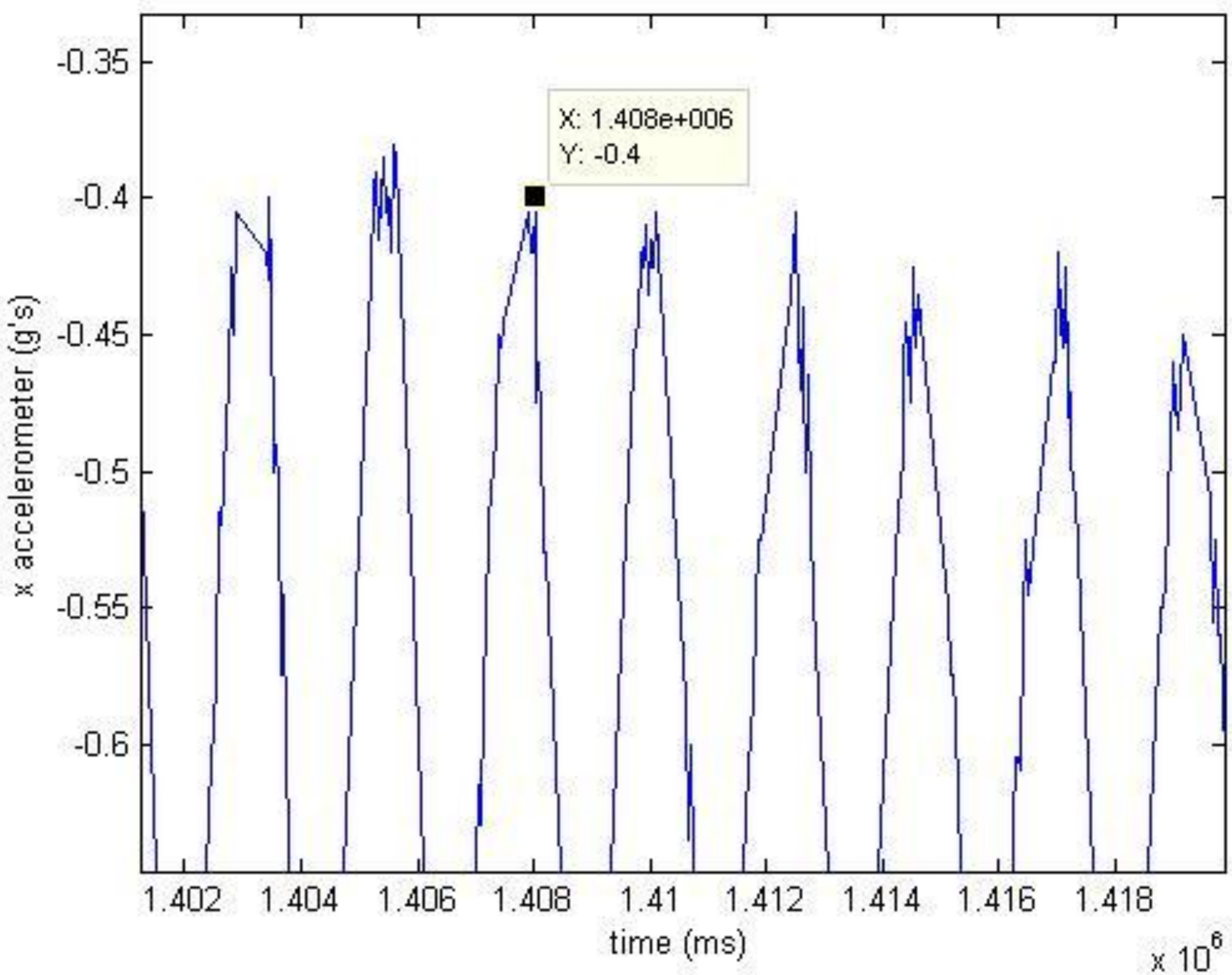
Pitch Inertia Test

Time vs. X accelerometers (zoom)



Pitch Inertia Test

Time vs. X accelerometers (zoom)



Pitch Inertia Results

- T (period) is the time difference from peak to peak
- Took average of every period
- T = 2.2 seconds

Pitch Inertia Results

$$I'_{yy} = \frac{WT^2L}{4\pi^2}$$

$$I_{yy} = I'_{yy} - \frac{WL^2}{g} - I_{rig}$$

Use same method as I_{xx}

Pitch Inertia Results

Measured

$$I_{yy} = \boxed{4.478\, slugs \cdot ft^2}$$

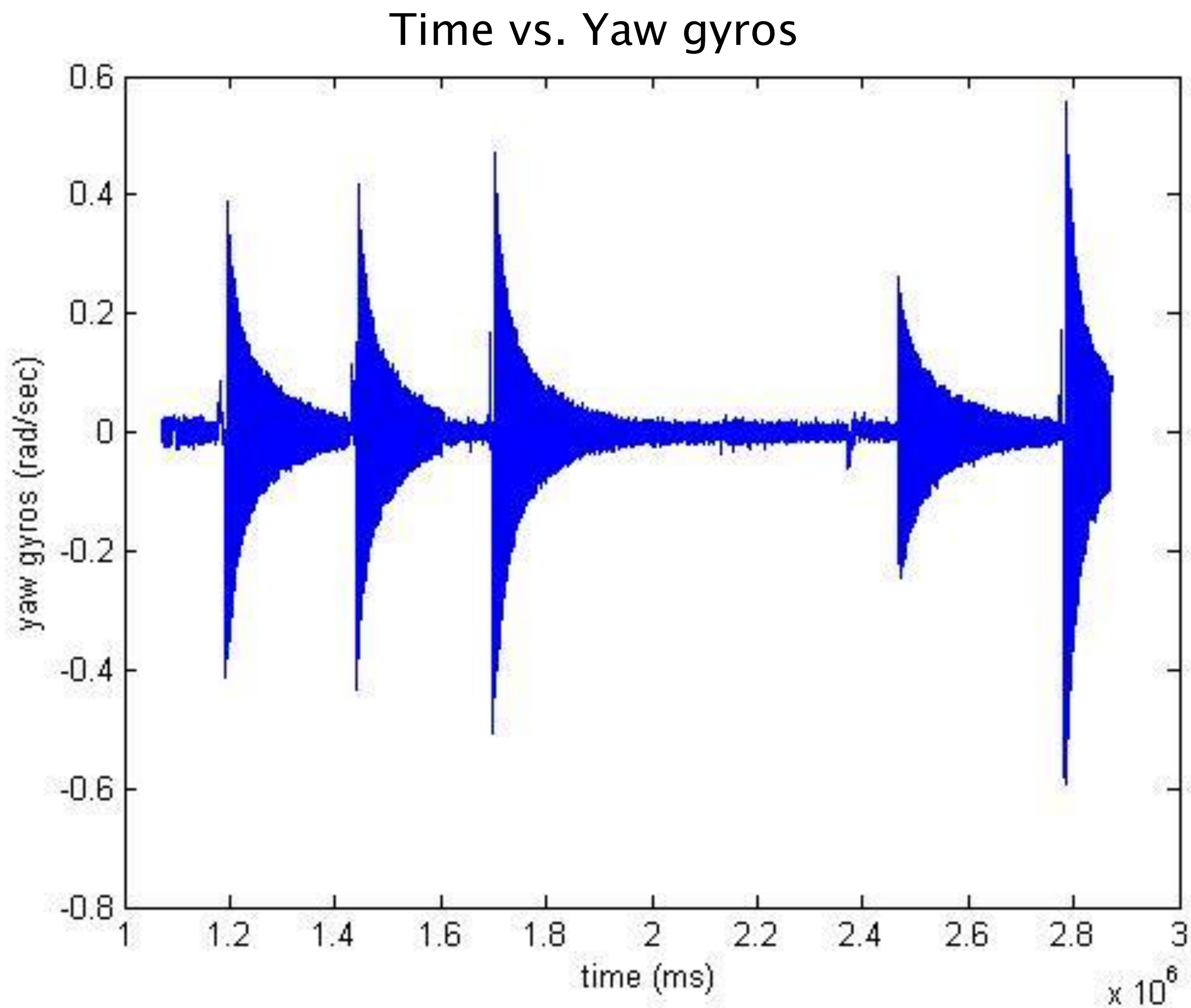
Estimated

$$I_{yy} = \boxed{3.862\, slugs \cdot ft^2}$$

Percent Error

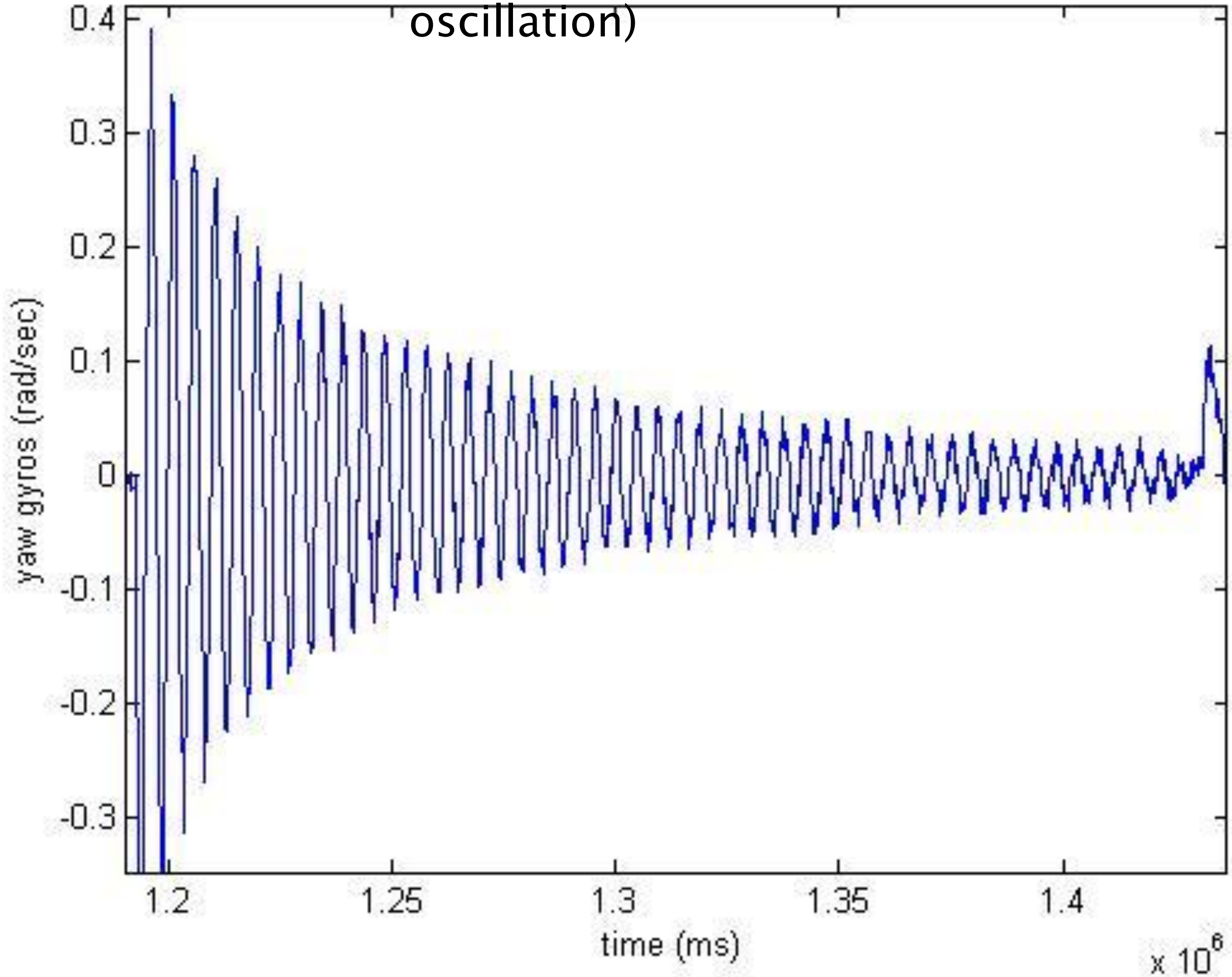
15.95%

Yaw Inertia Test



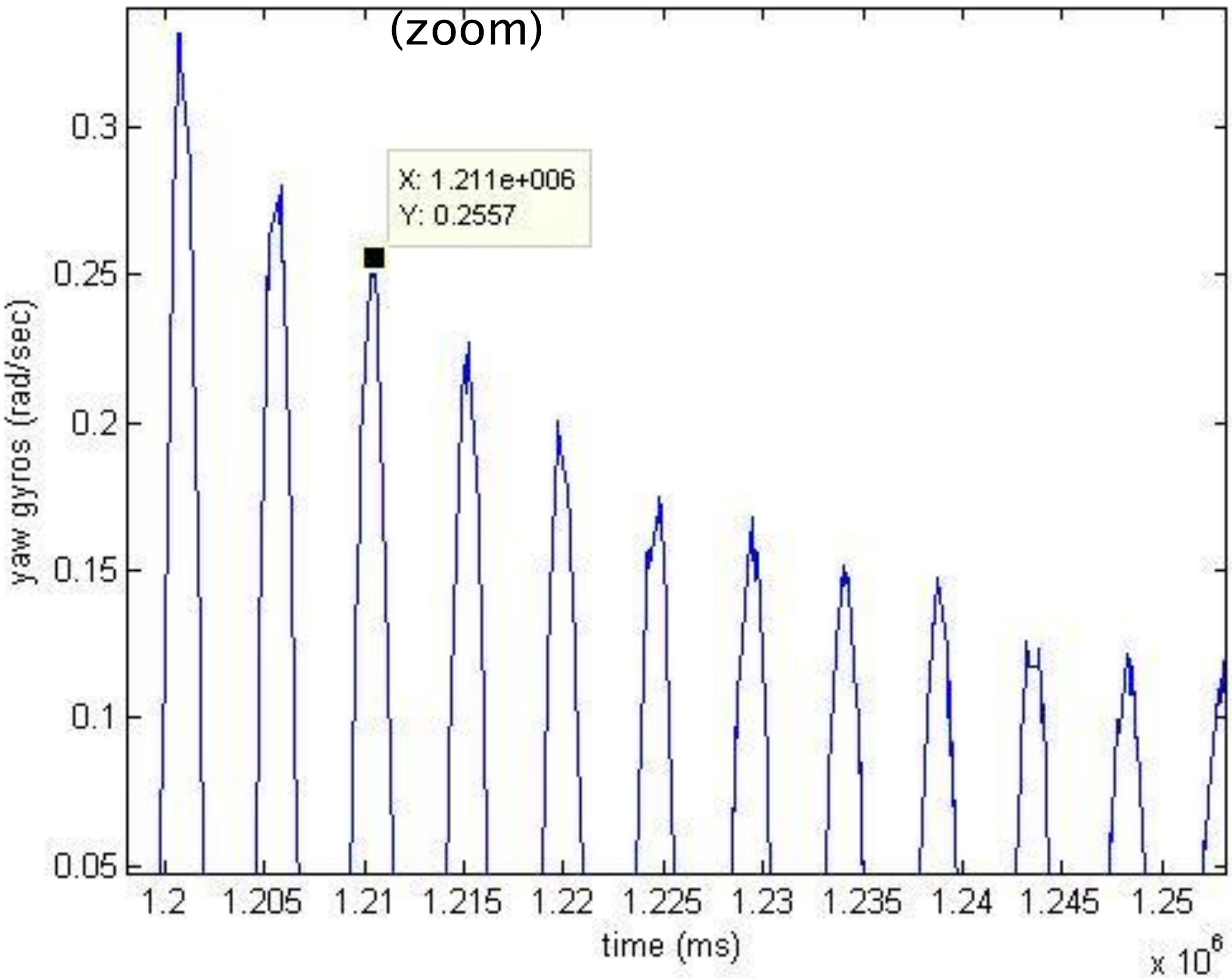
Yaw Inertia Test

Time vs. Yaw gyros (1 oscillation)



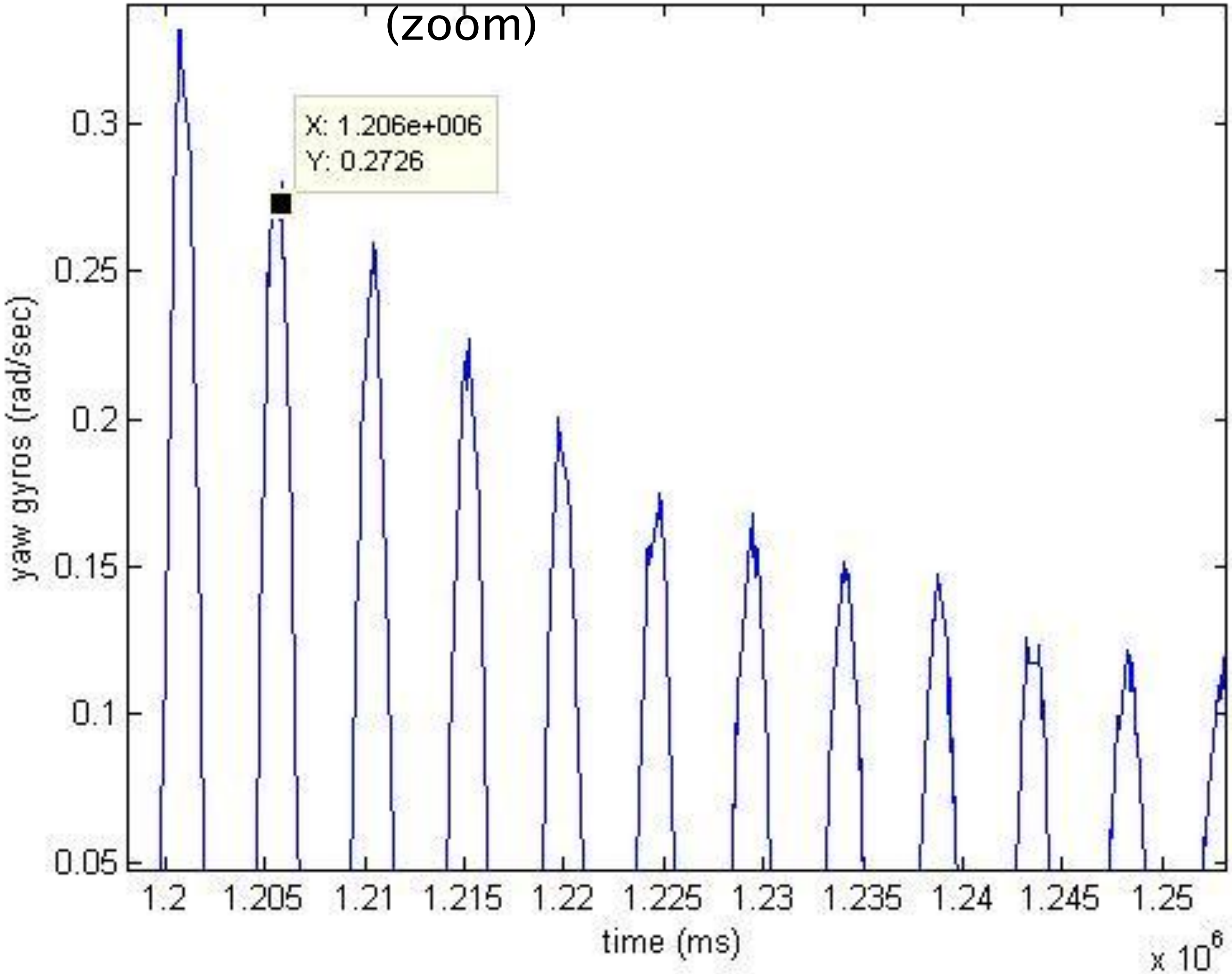
Yaw Inertia Test

Time vs. Yaw gyros (zoom)



Yaw Inertia Test

Time vs. Yaw gyros (zoom)



Yaw Inertia Results

- T = 4.7 seconds

$$I_{zz} = \frac{gT^2 d^2 W}{16\pi^2 l} - I_{rig}$$

g= gravity constant (ft/sec²)

T= period (sec)

d= distance between cables (ft)

W= weight of aircraft and rig (lbs)

L= length of cables (ft)

$$I_{zz} = \frac{\left(\frac{32.2ft}{sec^2}\right)(4.7sec)^2(2.104ft)^2(51.115lbs)}{16\pi^2(5.25ft)} - 0.4692\ slugs \cdot ft^2$$

Yaw Inertial Results

Measured

$$I_{zz} = \boxed{2.4228\ slugs \cdot ft^2}$$

Estimated

$$I_{zz} = \boxed{6.3976\ slugs \cdot ft^2}$$

Percent Error

62.13%

In Conclusion

- Not all, but most predictions in our CDR were confirmed.
- We all learned a lot about math, physics, and aeronautics through this project.
- We are all really grateful for the time we have spent here, and those who have helped us at Dryden.

Questions?